TECHNICAL

ASSIGNMENT 4

Deciphering Dementia- A Within-Subject and Between-Subject Analysis Using Mixed Effects ANOVA

INF2178

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Introduction:

In my investigation, I meticulously explore the nuanced progression of cognitive decline across various temporal milestones. By examining the cognitive shifts in individuals diagnosed with and without dementia using a mixed-effects ANOVA approach, I aim to unravel the typical trajectory of cognitive aging and the individual variances observed over time. My study engages both within-subject (temporal) and between-subject (dementia status) factors to shed light on the complexities of cognitive decline. This approach aids in identifying variables that may influence this variability, thereby deepening my understanding of cognitive aging and dementia.

Research Questions:
To understand the effects of dementia on cognition, I plan on answering the following questions:

RQ1: "How do Mini-Mental State Examination (MMSE) scores evolve over time in individuals diagnosed with dementia compared to those without? Moreover, does the rate of change differ between the two groups?"

RQ2: "Do MMSE scores change over time in a manner dependent on gender? If so, in what way does gender influence the trajectory of cognitive change as reflected by the MMSE?"

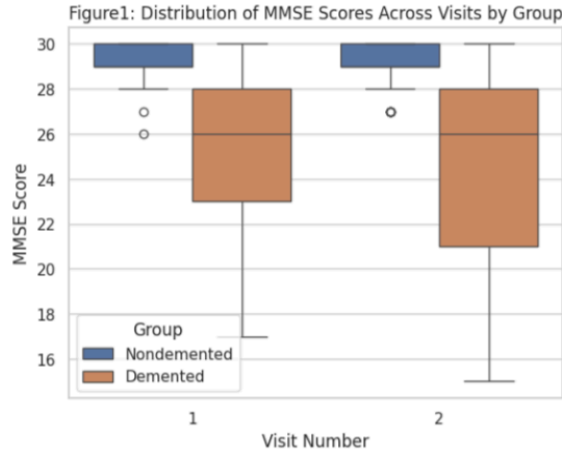
RQ3: "What sample size is necessary in future studies to detect an effect size of 0.7 with 91% power and a 5% alpha level?"

Data Cleaning and Preparation:

In my research, I found that not all variables were relevant to my investigative questions, leading me to retain only a select set of columns: ‘Group’, ‘Visit’, ‘MMSE’, ‘M/F’ and ‘Subject ID’. I came across missing MMSE scores and opted to remove these instances to maintain the integrity of my data. This careful data cleaning is crucial for the validity of my findings. As my interest centers on the comparison between Non-demented and Demented individuals, I removed entries from the ‘Converted’ group. Further examination into the dataset necessitated the classification of ‘Visit’ and ‘Group’ as categorical variables, which I adjusted during the initial stages of data preparation. I also dropped the ‘Converted’ group from the boxplot visualizations.Lastly, I changed the name of the ‘M/F’ column to ‘Sex’ to make it easy to work with.

Exploratory Data Analysis:

Figure 1 provides a clear depiction of MMSE score distributions divided between dementia and non-dementia groups over two consecutive assessments (Visits 1 and 2). The dementia group displayed a notable drop in median MMSE scores from the first to the second visit, suggesting a



decline in cognitive ability. Initially, on visual inspection, the IQR for this group is tight, indicating concentrated MMSE scores, but it widened in the following visit, revealing greater score dispersion. Conversely, the non-dementia group maintained stable median MMSE scores, with the absence of outliers reinforcing the consistency of cognitive performance within this group. Future research might explore how age, gender, education, and socioeconomic status influence cognitive outcomes.

Addressing RQ1:

Null Hypothesis (H0): MMSE scores do not change significantly over time in individuals diagnosed with dementia compared to those without dementia, and the rate of change in MMSE scores over time is the same between individuals with and without dementia.

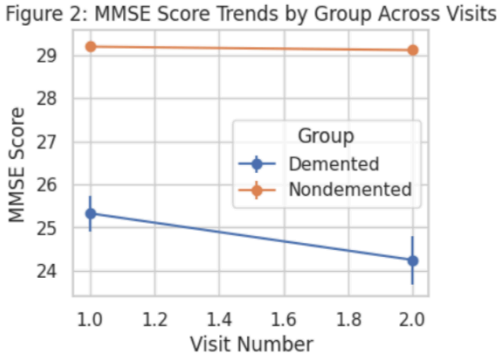
To answer RQ1, I closely analyzed the MMSE score trends among two groups, differentiated by dementia status, as reported in Table 2. I also performed a mixed-design ANOVA, detailed in Table 1, which considered both dementia status (Group) and time (Visit). The results indicated a pronounced difference in cognitive scores between the demented and non-demented groups, with a significant group effect (F-value of 56.212, p-value < 0.001, ηp^2 = 0.445). This suggests that dementia status contributes substantially to the variability in cognitive performance. Further examining the time effect in Table 1, I observed that time influences cognitive scores (F-value of 8.359, p-value = 0.003, ηp^2 = 0.056), albeit to a lesser extent than dementia status. Moreover, the interaction effect between group and visit also appears significant (F-value of 3.365, p-value = 0.037, ηp^2 = 0.046), as per Table 1, indicating the differing trajectories of cognitive progression between the two groups over time.

TABLE 1: ANOVA SUMMARY

Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
Group	1328.421	2	140	664.211	56.212	0	0.445	nan
Visit	22.378	1	140	22.378	8.359	0.003	0.056	1
Interaction	17	2	140	8.5	3.365	0.037	0.046	nan

TABLE 2: SUMMARY STATISTICS OF MMSE

Visit	Group	Mean	Std
1	Demented	25.33	3.32
	Nondemented	29.19	0.85
2	Demented	24.25	4.4
	Nondemented	29.11	0.96



From Table 2, it was observed that individuals in the dementia group experienced a decrease in MMSE scores, dropping from an average of 25.33 to 24.25 across the two visits, hinting at cognitive decline. In stark contrast,

the non-demented group's MMSE scores remained stable, with means of 29.19 and 29.11, showcasing a lack of notable cognitive change over the study period. The small standard deviations reinforce the stability of cognitive function in the non-demented group, contrasting the cognitive decline observed in the demented group.

TABLE 3: LEVENE'S TEST FOR HOMOGENITY		
Test	Statistic	p- value
Levene's	1.64	2.00E-01

My analysis suggests that both dementia status and time—separately and interactively—are significant factors in the progression of MMSE scores, as evidenced by the ANOVA outcomes in Table 1 and the MMSE scores in Table 2. The results underline the importance of considering both factors when evaluating cognitive evolution in dementia research.

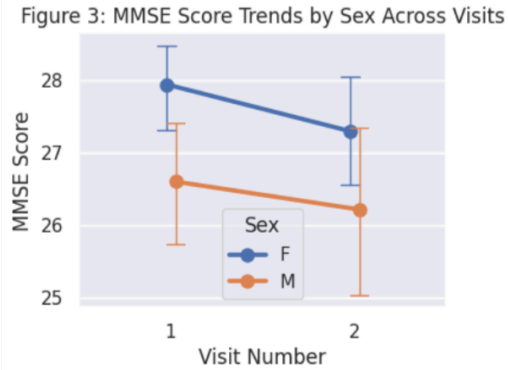
TABLE 4: SHAPIRO-WILK TEST FOR NORMALITY		
Visit	Statisitc	p value
Visit 1	0.781	1.76E-13
Visit 2	0.761	5.43E-14

The homogeneity of variances, as showcased by the Levene test presented a W-statistic of 1.64 and a p-value of 0.2. Since this p-value exceeds the standard significance level of 0.05, it suggests that I cannot discard the null hypothesis, which postulates that variances across groups are consistent. My application of Mauchly's test of sphericity yielded a value of 1, which informs me that the assumption of sphericity within my dataset has not been breached. Additionally, when I conducted the Shapiro-Wilk test of normality for the first and second visits, I found the values $W = 0.781$, $p < 0.001$, and $W = 0.761$, $p < 0.001$, respectively. These results indicate that the data significantly deviates from a normal distribution.

In summary, I am inclined to reject the null hypothesis for both the main effects of group and time, as well as for the interaction effect between group and time, suggesting that MMSE scores do evolve differently over time in individuals with dementia compared to those without, and the rate of this change also differs between the two groups.

Addressing RQ2:

Null Hypothesis (H0): MMSE scores do not change over time in a manner that is dependent on gender, and there is no interaction effect between time and gender on the trajectory of cognitive change as reflected by MMSE scores.



In my investigation into the mixed ANOVA results, I explored how time and gender affect MMSE scores, an established measure of cognitive function. My analysis highlighted a statistically significant decline in MMSE scores over time, with an average drop of 0.769 points between the visits. Yet, gender didn't emerge as a statistically significant factor in this change; even

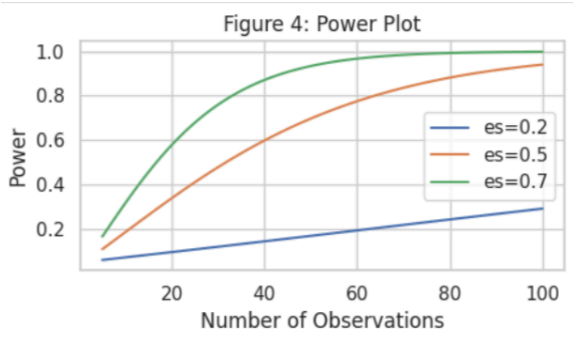
though the average scores for men were 1.312 points below those for women, the p-value of 0.018 for this difference didn't meet the usual standards for statistical significance.

Table 5: Mixed Linear Model Regression Results			
Term	**Coef**	**Std Error**	**P>|z|**
Intercept	28.102	0.358	0
C(Visit)[T.2]	-0.769	0.248	0.002
C(Sex)[T.M]	-1.312	0.556	0.018
C(Visit)[T.2]:C(Sex)[T.M]	0.476	0.385	0.217
Group Var	8.665	1.028	

Moreover, as evident from Table 5, the interaction between time and gender wasn't a significant contributor to the changes in MMSE scores, given the interaction coefficient of 0.476 and a p-value of 0.358. These findings underscore a trend in cognitive function over time but also highlight that gender wasn't the main influencing factor in this particular sample, indicating a need for further research into how and when gender might affect cognitive decline. As indicated in Table 3, the Levene test showed a W-statistic of 1.64 and a p-value of 0.2, which is above the typical significance level of 0.05. This suggests that the variances are aligned across the groups since we cannot dismiss the null hypothesis. The data exhibited significant deviations from a normal distribution, which is crucial to consider in my statistical analyses. Hence in light of the evidence provided, I am inclined to accept the null hypothesis.

Addressing RQ3:

In my theoretical design for an experiment with a power of 0.91, an alpha of 0.05, and an anticipated effect size of 0.7, I calculated that the appropriate sample size needed is 46 by using statistical power analysis (rounded to two decimal places to the nearest whole number from 45.45). Additionally, Figure 4 illustrates a power plot for tests with varying effect sizes—0.20, 0.50, and 0.70. The x-axis denotes the number of observations required, and the y-axis quantifies the power, which is the likelihood of detecting an existing effect. I observed that for a small effect size of 0.20, even 100 observations fail to achieve 80% power. Conversely, for medium (0.50) and significant (0.70) effect sizes, the power hits 80% at sample sizes ranging from 40 to 60 and just below 40, respectively. This plot is instrumental for me to estimate the number of observations necessary to discern effects of various magnitudes.



Conclusions: In my study, I discovered that both the status of dementia and the length of follow-up had a significant impact on MMSE score outcomes and that the trajectory of cognitive change during the follow-up period was markedly different between individuals with dementia and those without. Gender, on the other hand, did not emerge as the main factor influencing the changes in MMSE scores.